Massimo Tinazzi

The Correspondence between Alessandro Volta and Giuseppe Zamboni about the Realization of the "Dry Pile"

After the initial success of the first models of pile, Alessandro Volta[1] realized that some problems reduced the conservation of the piles and their efficiency, because performances deteriorated rapidly.

Since the beginning of the eighteenth century, a Veronese physicist, Giuseppe Zamboni (1776-1846), undertook a different way of research to manufacture "electrical dry piles", namely without the use of acids or other types of liquids that damaged the metals of the electromotive pairs.[2]

During the development of these piles, Zamboni had a short but intense correspondence with Volta, with whom he could discuss which solutions and substances to adopt in order to turn his piles into more efficient ones.

In 1812 Zamboni submitted to Volta the achievements of his work. Volta wrote back and proposed the use of "black manganese" (manganese dioxide) because it had a great quality in the "electromotive faculty".

Zamboni followed Volta's suggestions and developed the researches further. In this way he succeeded in realizing, in the following years, many dry piles with long and efficient operation, and he named them "perpetual electromotors", so he applied them to put small pendulums in oscillation and to operate clocks.

Alessandro Volta[3] had the opportunity[4] to undertake some correspondence with some Veronese scientists as Anton Maria Lorgna, Antonio Cagnoli and Agostino Vivorio president and secretaries of Academy of Forty, to publish a work about electricity in the Acts and Memoirs of Italian Society of Sciences founded by Lorgna.

[1] MARTINI (1898-9).
[2] ZAMBONI (1812); ZAMBONI (1820-2).
[3] MIELI (1927); MONTI (1844); POLVANI (1949).
[4] See lettera a Giuseppe Zamboni, Como, 8 settembre 1812, in *VE*, V, pp. 242-3.

However the most interesting scientific relations were with Giuseppe Zamboni as we can read in some letters sent by Zamboni to Volta[5] and in the related replies (collected in the volumes *Opere di Alessandro Volta* and *Epistolario di Alessandro Volta*) that cover a brief period of two months, August and September 1812.[6]

Figure 1 The portrait of Giuseppe Zamboni in a drawing.

Since 1800 Zamboni[7] began long experimental work to set piles with the main characteristic of longer duration than the first electric columns. He aimed to improve Voltaic piles which deteriorated rapidly because of the presence of an acid. The aim was to realize the "dry" piles, trying to eliminate the substances that caused the corrosion of metallic elements.[8]

The pile was a great step forward, so much so that Davy "in 1810 considered Volta's battery as the getting up for all European experimenter",[9] but theory had some defects in addition to the practical disadvantages which affected the pile. First

[5] TINAZZI (1997a).
[6] TINAZZI (1996); TINAZZI (1998).
[7] GIRARDI ed. (1861).
[8] TINAZZI (1998).
[9] ABBRI and TORRACCA (1988), p. 301.

the zinc was consumed under the action of sulphuric acid, also when the pile didn't supply current, and this event was a useless waste. Yet, if the acid was not put in the water, the pile supplied a much weaker current and another drawback happened: polarization.

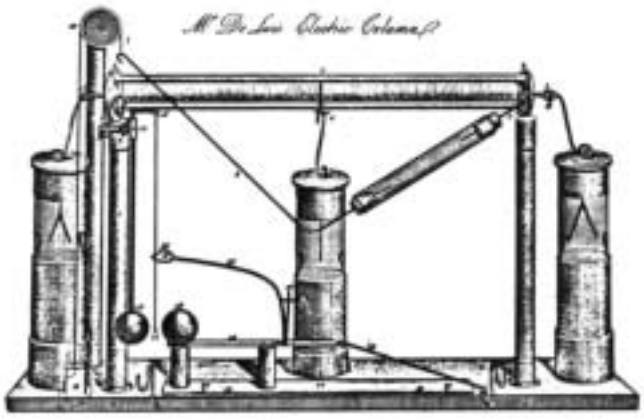

Figure 2 De Luc Piles.

Besides, the acid solutions corroded the felts or the small discs of cloth put between the metallic pairs. So it was necessary to clean up the latter, losing some of their substance. Furthermore, when the felts were dry the pile didn't operate. Volta was aware of this problem and in fact in a memoir read at the National Institute of France, on the identity of the electric and the Galvanic fluids,[10] he said: "Maybe one day someone will succeed in building a completely solid electromor! [...] It is very difficult, but not impossible".

Naturally the idea of excluding chemical substances that deteriorated the metallic pairs was not new, in fact it was attempted by Volta himself, J.W. Ritter, and Behrens (with copper, zinc and gold foil).

In this way he gave the scientists a first start to continue their research. Immediately, no physicist had tried to solve the cited drawbacks.[11] Later, notable modifications were devised by Wollaston, Joung, Muncke and Oersted. In 1803 Hachette and Désormes[12] realized a column in which they replaced the small discs of wet cloth with small plates of dried paste mixed with sea salt; but this didn't give reliable operation and had other problems like mould.[13] Biot thought of replacing

[10] ZAMBONI (1846); GIACOMELLI and GIACOMELLI (1999).
[11] DE BENEDETTI (1967).
[12] DE LA RIVE (1833).
[13] GLIOZZI (1937); GLIOZZI (1965).

the paste with a plate of fused nitre (salpetre), Becquerel tried to put hot glass between the two metals, with the function of electrolytic liquid. Buff[14] overlapped plates of zinc, glass and brass, but it was necessary to expose the instrument to hot air coming from a lamp to get it to work.[15]

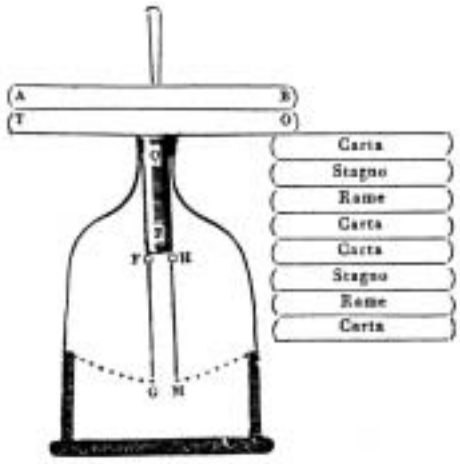

Figure 3 Copper and zinc pairs with electrometer (left) and electromotive pairs separated by paper coated with manganese oxide (right), from *L'Elettromotore perpetuo* by G. Zamboni, vol. II, pp. 39 and 65.

We can understand that all these piles were lacking in comfort of use and operated in particular conditions.

These problems were known by Alessandro Volta when he wrote to reply to Zamboni's[16] first letter in which he asked for an opinion about the structural arrangement and the quality of his piles, at this point very satisfying. Zamboni wrote:

> If the problem is the increase in electric energy with the increase in the number of pairs, without interposition of a wet body between them, I can say I have solved it.[17]

[14] ZAMBONI (1845).
[15] RIGHI (1874).
[16] See lettera a Giuseppe Zamboni, Como, 8 septembre 1812, in *VE*, V, p. 242 [also in GLIOZZI (1967) pp. 593-4].
[17] ZAMBONI (1812).

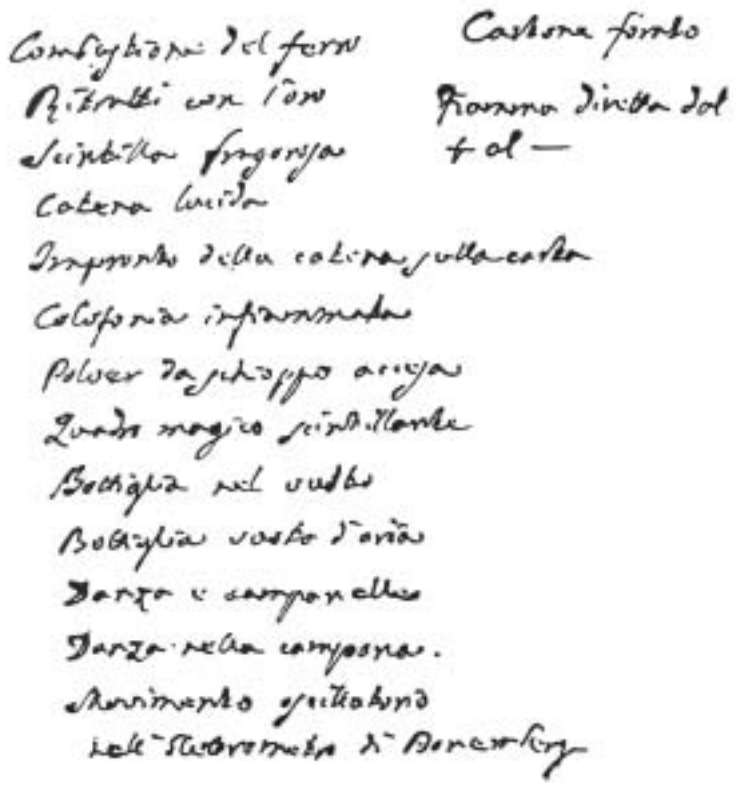

Figure 4 Zamboni's autograph kept at the Liceo Classico Virgilio in Mantua, with a list of materials used to construct the piles.

Already in 1809 De Luc[18] planned and realized a new column as a source of static electricity, perhaps improving on Zamboni. The results of his experiments were communicated to the Royal Society, but for some reason they are not published in the *Philosophical Transactions*, so de Luc reached new results as shown by an article published in two parts in the issue of October-November of Nicholson's Journal of 1810.

While Zamboni was positively finishing his experiments in 1811, he read about the De Luc column, but he wrote: "It is necessary to consider the very different way followed by Mr. De Luc to reach his invention, and my instrument much simpler, convenient and surer in its effect [...]".

[18] DE LUC (1811).

In any case De Luc's pile still had some defects. The disposition of metallic plates was more complex, besides it didn't produce very relevant effects as Zamboni's pile. On the other hand when Poggendorff[19] analyzed the attempts to realize dry piles he didn't mention the work of De Luc but he mentioned Zamboni's pile as "discovered by Zamboni himself".

Figure 5 A disassembled model of the cell unit of Zamboni's dry pile for didactical use.

In fact Zamboni in the same period was aware that

> the Voltaic column, because of the oxidation of two moistened (wet) metals by acid and salty solution, contained the germ of its own destruction. The solid conductor cannot be used in place of water, because its electromotive force would have broken: this concept was expressed by theoretical Voltaic principles and experimental studies. However it was a good idea to search among the bodies containing some traces of humidity, to give way to the electric fluid while not damaging metals. And at the same time wouldn't the voltage (almost not detectable because of its smallness), with more imperfect effect of the conductor, be doubled so as to obtain some useful effects?[20]

Since 1810 the originality of his ideas must be considered in this way because the theoretical and experimental realization was the building of the "dry pile". An interesting characteristic was the small dimension in which he managed to crowd thousands of electromotive pairs to increase the voltage. For this purpose he devised

[19] POGGENDORFF (1863).
[20] ZAMBONI (1812).

also some instruments to build in the specific shape and to pack with the most suitable sealing.

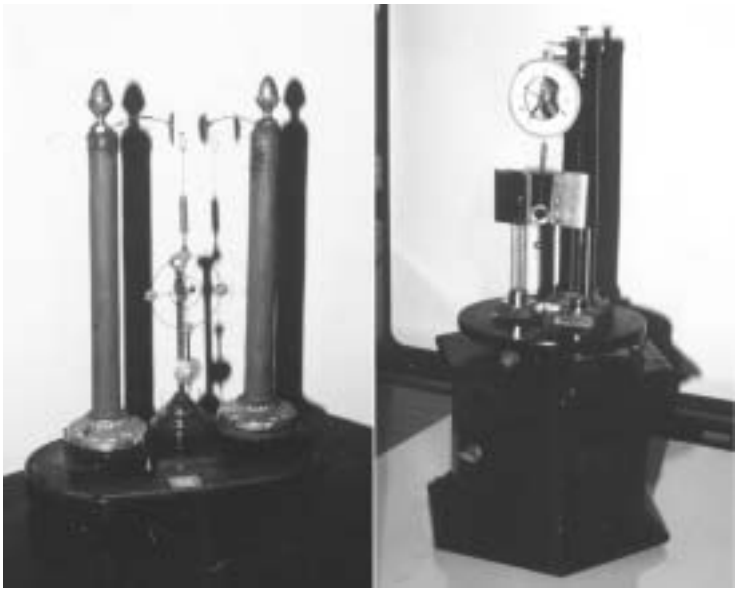

Figure 6 Two Zamboni realizations: on the left picture the pendulum (perpetual electromotor) kept in Verona College "S. Maffei", and on the right picture the clock supplied by dry piles, kept in Mantua College "Virgilio".

When Zamboni was satisfied with the efficiency of his batteries he wrote to Alessandro Volta to present him the results of his work. Analyzing this brief but intense correspondence we can note that Zamboni followed and went beyond Volta's suggestions, and in the next decades he succeeded in realizing many dry batteries with long time efficiency that he called "perpetual electromotors", applied to the oscillation of small pendulums and to the operation of clocks.

Zamboni had great admiration for Volta, in fact in the publication "Esame di una memoria del sig. Buff intorno all'elettroforo e sulla migliore costruzione di questa macchina" he began with: "The greatest Italian electrician has made known, since 1775, the Electrophorus named after him, and he entirely explained the phenomena with a clear theory, which both the schools of Franklin and Symmer adopted, each in its own language".

In the first letter of August 24 Zamboni explained his technique for building his batteries:

> [...] The electromotive power of plumbago in contact with silver paper is greater than that with copper, so I thought of putting it in place of the gold foil in order to increase the

effect of the machine with the same number of pairs. So I spread a layer of plumbago on the reverse of the silver paper, and so I built a pile obtaining more than a tripled effect.[21]

In September of the same year Volta answered him with two letters suggesting the use of "black manganese" (dioxide of manganese) due to its excellent quality in the "electromotive power [...] superior to plumbago and the best charcoal". After having experimented the use of zinc sulphate pulverized and dissolved in water, Zamboni used black and friable manganese oxide dissolved in water with the addition of a little quantity of paste. In fact the main problem resulted from the fixing of manganese dioxide that was made adherent on plates also with fats, or mixtures bound with rape oil or milk, or with honey: then the mixtures were suspended in a very concentrated solution of zinc sulphate.

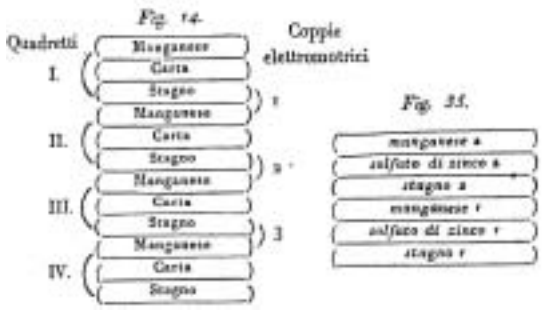

Figure 7 The different elements which were used by Zamboni to experiment some mixing of cells, from *L'Elettromotore perpetuo*, vol II.

In the second letter of September 12 he explained how he had followed the received advice and reported the results obtained:

To spread the pulverized charcoal on the reverse of the silver plate in place of the plumbago about which I told you in my second letter. First I cover the reverse of the above-mentioned paper, then I spill on it the charcoal: or after having dissolved it, previously pounded, in soap-suds I spread it with a paint-brush [...] my little machine is not rigorously a dry pile but it can however be named in this way [...] the humid is really a cause that produces contrary and complicated effects in the apparatus.[22]

In the introduction to the paper *Della pila elettrica a secco* there were already the elements of this correspondence between Zamboni and Volta:

There is no-one among the lovers of natural sciences who contemplated the admirable effects of the Voltaic Pile, who is not embittered by the damage produced by the acid or salty solutions on it, solutions with which the cardboards interposed between the metallic

[21] See lettera di Giuseppe Zamboni ad Alessandro Volta, Verona, 24 agosto 1812, in *VE*, V, p. 242.
[22] See lettera di Giuseppe Zamboni ad Alessandro Volta, Verona, 8 settembre 1812, in *VE*, V, p. 242.

> pairs are sodden. The absence of any effect when the humid body becomes dry, the contaminating oxidation of metals of which they have to be cleaned, with waste of their substance, besides the not minor problems that the experimenter has, they hide for ever those phenomena that require a perennial continuation of the electric charge in the Pile. So I think there isn't any physicist who doesn't wish to free so valuable an instrument from so many problems, and to make a perpetual electromotor with a dry Pile. Truly the immortal Author of this machine has demonstrated, since the first time of this discovery, that it is impossible to realize such apparatus by replacing the humid bodies with some conductors of the first class (Volta distinguished the electric conductors in two classes: the metallic conductors or "first class", and the humid body or "second class"): metals i.e. pyrites, minerals and charcoals; however he doesn't completely despair of finding other substances. "Who knows (such are his words) [Memoir of Volta held at the National Institut of France, on the identity of the electric and the galvanic fluids] that one day it will be possible to build this electromotive apparatus completely solid? We must find some solid conductor good enough, which is purely conductor and not motor, or also motive but in other relation rather than that one regular and graduated that we note in metals; and we held to interpose that one, instead of humid conductors between the usual pairs of different metals. This thing seems very difficult but not impossible. Now if the problem is to increase the electric energy increasing the number of pairs without interposition of a moistened body between them, I can say I have solved it perfectly. But what happens? While I was achieving the expected result in my way, the volume of British Library n° 370 Sciences and Arts (May, 1811) arrived and in it I saw I had been anticipated by a very respectable physicist, Mr. De Luc, finding there described by him the named electric column that already existed in another shape in my laboratory. […] Anyway, you have to consider the very different way followed by Mr. De Luc, you have to consider my apparatus very much simpler and more convenient, and surer in its effect; and I will be satisfied with that reward that the sage and discreet reader will judge suitable to the service that I have rendered to science.[23]

Zamboni's pile was formed of 2,000 or more plates of commercial silver paper, made of paper with a thin layer of tin or copper-zinc alloy (named tombacco) spread on it. On this metallic surface he spread pulverized charcoal mixed with water or nitric acid.

An important element in Zamboni's batteries was the technical building for packing the plates. They were inserted in glass tubes painted inside and externally with insulating mastic. The little humidity contained in common paper was sufficient to allow the transit of electricity. The small quantity of humidity and the adhesion of particles to the paper soaked in them corrodes metals only over a very long time, moreover the thin veil of oxide that was produced served as protection against further oxidation. The problem of checking the batteries was not a secondary factor but the main way of experimentation, because he needed evaluating their behaviour in time and their sensibility to local weather conditions.

[23] ZAMBONI (1812).

The problem of insulating the disc columns, also considered by Volta[24] made the effects of electric power unstable, so much that he wrote to Zamboni: "It is impossible to calculate exactly such complicated effects in different circumstances, but it is easy to evaluate them roughly; and to point out how favourable is the influence of the humidity of the paper disks or similar, it is sufficient to keep the pile one or two days in a humid place, and then to expose it in a properly dry place. To point out the harmful influence of external humidity, it is sufficient to induce on purpose such surface humidity; and if finally we provide more humidity to these papers, in the way shown, and at the same time more dryness to the exterior surface of the pile, exposing it shortly to a fire breeze or to the sun's rays, we shall obtain all that vigor and quickness of electric effects, so this pile is not rigorously a dry pile but we can name it this way".[25] Volta appreciated the solution adopted by Zamboni to put small pendulums in oscillation, so he wrote in a letter:

> Mr. De Luc and You [...] have largely surpassed me [...] above all in the almost perpetual oscillations of small pendulums (another kind of electrometer) fitted in De Luc's way, and in the really perpetual oscillations of magnetic needle fitted in your way, distinguished Professor, in the finest, convenient and elegant little machine You have so well imagined and described, which I like very much and I cannot stop lauding.[26]

The pile realized by Zamboni was covered with melted colophony (or Greek pitch, a resin that got its name from Colofone and it was the remnant of preparation of oil of turpentine), then plastered with virgin wax, which didn't absorb the humidity of the paper discs, and in the end covered with insulating paint. The main problem that makes these piles very difficult to reconstruct is to find the original material used in the past.

These batteries produced a difference of potential of some thousands of volts and currents in microamperes. The structural arrangements guaranteed the operation for very long periods due to very slow polarization. This very inviting characteristic of dry piles gave an exceptional length of time due to the fact that if their use is stopped for a short period, it is possible to obtain a partial recharge, because of the capture of atmospheric humidity. In fact later the Veronese physician understood that he had not to insulate the batteries completely but that it needed an opening making communication with the external ambient.

To confirm this feature Zamboni wrote that some of his pendulums worked for some years without ever stopping. Moreover a pair of piles put in operation on May 18, 1839 at the Modena Institut of Physics operated almost incessantly for 100 years.[27]

[24] VOLTA (1967); GIACOMELLI and GIACOMELLI (1999).
[25] Lettera a Giuseppe Zamboni, Como, 8 settembre 1812, in *VO*, IV, p. 285-8 [also in GLIOZZI (1967)].
[26] *Ibid.*.
[27] PIERUCCI (1933).

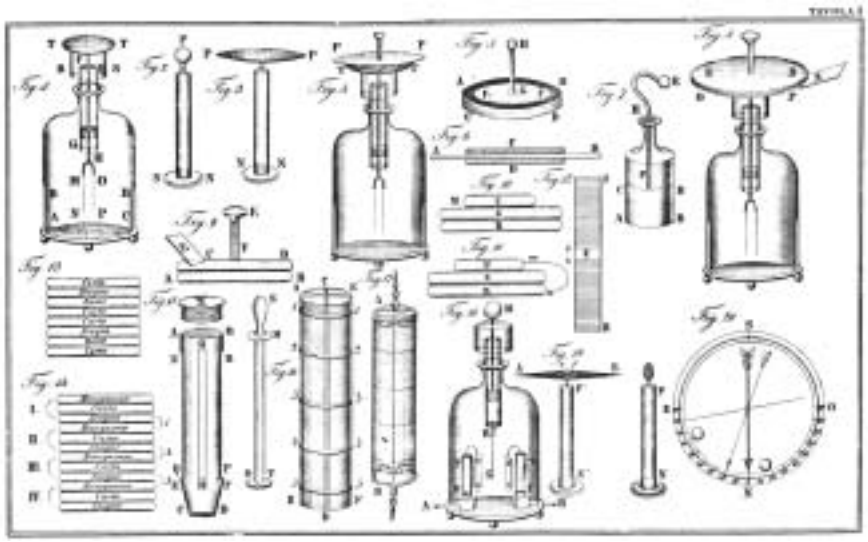

Figure 8 Instruments for the construction of piles realized by Giuseppe Zamboni, from *L'Elettromotore perpetuo*, table 2.

This perpetual electromotor consists of a very light little pendulum pivoted on an axis that moves between two platinum electrodes about 3 cm apart and linked to the batteries.

The pendulum consists of a platinum wire, about 10 cm in length, soldered to two metallic concentric rings. The internal ring is supported by a very light axis which rests on two horizontal supports of quartz.

BIBLIOGRAPHY

ABBAGNANO, N. (1965), *Storia delle scienze*, Torino: UTET, 1965, II.

ABBRI, F., TORRACCA, E. (1988), "L'elettrochimica", in *Storia della Scienza Moderna e Contemporanea*, Torino: UTET.

DE BENEDETTI, R. (1967), *Uomini della elettricità*, Torino: ERI, 1967.

DE LA RIVE, A.A. (1833), "Esquisse hystorique des principales decouvertes faites dans l'élettricité depuis quelques années", *Bibliothéque universelle*, 3 (1833), pp. 520-35.

DE LUC, G.A. (1811), "Sciences et Art", *Biblioteca Britannica*, 370 (1811), pp. 332-3.

GIACOMELLI, G., GIACOMELLI, R. (1999), "Galvani e Volta, scoperte e controversie", *Sapere*, 3 (1999), pp. 57-63.

GIRARDI, L.A. ed. (1861), *Opere scelte di Alessandro Volta*, Torino: Unione Tipografico-editrice, 1861.

GLIOZZI, M. (1937), *L'Elettrologia fino al Volta*, Napoli: Loffredo, 1937.

ID. (1965), "Storia della Fisica", in ABBAGNANO (1965).

ID. ed. (1967), "Lettera all'abate Zamboni sulle pile a secco", in VOLTA (1967), pp. 593-4.

HEILBRON, J.L. (1984), *Alle origini della fisica moderna*, Bologna: Il Mulino, 1984.

MARTINI, T. (1898-9), "Intorno alle scoperte di Alessandro Volta", *Atti del Reale Istituto Veneto di Scienze, Lettere ed Arti*, 58 (1898-9), pp. 113-20.

MIELI, A. (1927), *Alessandro Volta*, Roma: Formiggini, 1927.

MONTI, M. (1844), "Volta Alessandro", in *Biografia degli italiani illustri*, Venezia: Cecchini, IX, 1844, pp. 258-89.

PIERUCCI, M. (1933), "Il centenario dell'orologio elettrico", *Nuovo Cimento*, (serie 8), 10 (1933), pp. XVI-II.

POGGENDORFF, J.C. (1863), *Biographisch-Literarisches Hand Wörterbuch (zur geschichte der exacten wissenschaften)*, Lipsia: Barth, 1863.

POLVANI, G. (1949), "Volta Alessandro", in *Enciclopedia Italiana*, XXXV, 1949, pp. 572-6.

RIGHI, A. (1874), "Le pile secche", in SELMI ed. (1874).

SELMI, F. ed. (1874), *Enciclopedia chimica ed industriale*, Torino: UTET, 1874.

TINAZZI, M. (1996), "Zamboni, Giuseppe (1776-1846)", in *Lexicon der Elektrotechniker*, Berlin, VDE-Verlag GMBH, 1996.

ID. (1997), "Perpetual electromotive of Giuseppe Zamboni. Manufacture, comparisons and develops", in TUCCI, P. ed. (1997), pp. 667-715.

ID. (1997a), "The life and work of Giuseppe Zamboni in the light of his unpublished letters, in TUCCI, P. ed (1997a), pp. 291-309.

ID. (1998), "Zamboni e l'elettromotore perpetuo", *Sapere*, 6 (1998), pp. 53-62.

TUCCI, P. ed (1997), *Atti del 16. Congresso nazionale di storia della fisica e dell'astronomia*: Centro Volta, Villa Olmo, Como, 24-25 maggio 1996, Como: Gruppo di lavoro per le celebrazioni voltiane, 1997.

TUCCI, P. ed (1997a), *Atti del 17. Congresso Nazionale di storia della fisica e dell'astronomia*, Centro Volta, Villa Olmo, Como, 22-25 maggio 1997, Milano: Università degli studi di Milano, Istituto di fisica generale applicata, Sez. di storia della fisica, 1997.

VOLTA, A. (1889), "Commentario teorico-sperimentale di macchine ed apparecchi elettrici", Milano, Editori della rivista *l'Elettricità*.

VOLTA, A. (1967), *Opere Scelte di Alessandro Volta*, Torino: UTET, 1967.

ZAMBONI, G. (1812), *Della pila elettrica a secco. Dissertazione*, Verona: Dionigio Ramanzini, 1812.

ID. (1820-2), *L'elettromotore perpetuo*. *Trattato […] diviso in due parti*, Verona: Tipografia Erede Merlo, 1820-2.

ID. (1845), *Esame di una memoria del sig. Buff intorno all'elettroforo e sulla migliore costruzione di questa macchina*, Venezia: Giuseppe Antonelli, 1845.

ID. (1846), "Trattato di Conciliazione degli Elettrochimici coi Voltiani", *Atti delle adunanze dell'I.R. Istituto Veneto di Scienze Lettere ed Arti*, 5 (1846), pp. 429-41.